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TOWARDS THE INTEGRATION OF COMPUTER SIMULATORS "CIRCUIT WIZARD" AND "INTERACTIVE PHYSICS" IN THE LEARNING OF ELECTRICITY AND MECHANICS. CASE OF THE UNDERGRADUATE STUDENTS OF ISTA/KINSHASA

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A R T I C L E I N F O

Keywords:
Computer simulation; mechanics; electricity; Interactive Physics; Circuit Wizard

A B S T R A C T

Nowadays, there is no doubt that the computer simulator is considered one of the didactic materials generally used in the learning of physics, particularly in the fields of mechanics and electricity. This is because it allows the simplification of studied phenomena and enhances students' motivation for physics. Indeed, the primary objective of this research is to enumerate the advantages of using computer simulation in the process of assimilating concepts related to physical phenomena. It also aims to evaluate the impact of the computer simulation software "Circuit Wizard" in the learning process of electricity concepts and "Interactive Physics" in the learning process of mechanics concepts among students at the Higher Institute of Applied Techniques in the city of Kinshasa (ISTA/Kinshasa). To assess this impact, we utilized an ad hoc questionnaire (n=100), incorporating a 4-point Likert scale. The results indicate that the two software tested had a positive and evident effect on our students' learning. Therefore, we can consider that the "Circuit Wizard" and "Interactive Physics" software can be employed by students in our host institution for their study of physical sciences. This usage will assist them in better comprehending the respective concepts of these two branches of physics.

INTRODUCTION

It has been nearly two decades since computer simulation has been increasingly utilized in the context of grasping physics concepts. Computer simulation is indeed a powerful tool that allows the study of the functioning of a system or a specific physical phenomenon directly from a computer.

According to Larouche (2013), the use of simulation in teaching and learning physics aims to simplify the learning process of this subject. Pedagogical use of computer simulation provides students with additional motivation for learning physics. With computer simulation, students can more easily engage with physics lessons independently, without necessarily relying on their teacher. They can explore physical phenomena or discover expected knowledge on their own. Several studies (Demba, 2020; Mahdi et al., 2017; Chekour et al., 2015; Spodniakkovà Pfefferovà, 2015; Droui and El Hajjami, 2014) conducted in recent years have confirmed the effectiveness of this practice by students in the process of learning physics concepts. The present research aligns with the logic of discovering the effectiveness of using computer simulation in the learning process of physics.

In this article, our objective is two-fold. Firstly, we aim to evaluate the advantages of computer simulation in the assimilation of concepts related to physical phenomena. Secondly, we will test the computer simulators "Circuit Wizard" and "Interactive Physics" with students from the Higher Institute of Applied Techniques in the city of

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Kinshasa (ISTA/Kinshasa). These simulators were proposed to address the challenging issue of the lack of practical work in physics, as observed in the mentioned school (N'djoli et al., 2021). To this end, we have articulated our research questions as follows: Do the computer simulation software "Circuit Wizard" and "Interactive Physics" simplify the learning of the phenomena studied in electricity and mechanics? Can the Circuit Wizard and Interactive Physics software be used in the learning of various mechanical and electrical phenomena at ISTA/Kinshasa?

THEORETICAL AND CONCEPTUAL BACKGROUND

The content of this part of our article is essentially focused on the definition and advantages of using computer simulation in the process of assimilating concepts of physical phenomena.

1. DEFINITION OF COMPUTER SIMULATION

According to the Office Quebecers of the French language (2015), computer simulation corresponds to a virtual representation of a phenomenon or an environment, facilitated by different computer terminals. According to Larousse.fr (2015), computer simulation refers to a "Representation of the behavior of a physical, industrial, biological, economic, or military process by means of a computer model whose parameters and variables are images of those of the process under study." In their article titled "Computer Simulations in Science Education: Contributions and Limitations," Droui and El Hajjami (2014) define computer simulation as computer programs with a simplified model of a system or process to be studied.

As for our perspective, we define computer simulation as a virtual representation of a physical phenomenon, the characteristics or functioning of which we seek to control. This is achieved through the use of a computer.

2. THE ADVANTAGES OF USING COMPUTER SIMULATION IN THE PROCESS OF ASSIMILATING CONCEPTS OF PHYSICAL PHENOMENA.

Chekour et al. (2015) state that computer simulation allows testing scenarios before implementing them. They further argue that it also enables the apprehension of latent phenomena and the visualization of phenomena and their consequences.

For Droui and El Hajjami (2014), computer simulation plays several important roles in acquiring concepts of physical phenomena. Indeed, these authors emphasize that simulation in this context allows for simplification, making real systems more accessible for exploration, acting as an alternative to experiments impossible to perform, and serving as an intermediary between theory and practice.

According to Ulukök and Sari (2016), computer simulation has a significant effect on learners' attitudes toward learning physics. As evidence, the majority of the participants in this study noted that it is indispensable for teaching and learning physics, increasing students' motivation to learn physics. They also stated that the use of computer simulation reinforces their understanding of the physics concepts already studied. However, for Kollöffel and de Jong (2013), computer simulation or virtual laboratories guarantee the best understanding of physics concepts.

Mahdi et al. (2017) further assert that computer simulation in physics learning allows for the immediate display of the results of the phenomenon being studied and the manipulation or analysis of variables and concepts explored in class. In other words, computer simulation allows learners to deepen their understanding of phenomena explored in class.

In summary, in the preceding lines, we have attempted to elucidate the various advantages of using computer simulation in the process of assimilating concepts related to physical phenomena.

PHYSICAL SETTING OF THE STUDY

The Higher Institute of Applied Techniques of the city of Kinshasa (ISTA-Kinshasa) is one of the public higher education institutes in the Democratic Republic of Congo. It was established in 1971 through the merger of three institutes: the Meteorological Training Center (C.F.M.), the Institute of Civil Aviation (I.A.C.), and the National School of Post and Telecommunications (E.N.P.T.).

In 1973, the institute adopted its current name. This higher institute serves as the physical framework for the present study.

It is worth noting that the courses offered at ISTA/Kinshasa are divided into two cycles. The first cycle is a four-year training program, with the first year dedicated to preparatory studies in mathematics, physics, and chemistry. The subsequent three years constitute the graduation phase. The first cycle of studies at this higher institution includes the following programs:

o Electricity section with an industrial electricity option;

o Electronics section with several specializations (industrial, switching, radio transmission, and radio television) in the third year;

o Mechanical section with an electromechanical option;

o Meteorology section with options in weather forecasting, instrument protection, agro-weather, and hydro-weather.

For our study, we only involved students from the mechanical section and those from the electrical section. All of them are undergraduates.

The second cycle of this higher institute in the city of Kinshasa includes the following sections:

• The electricity section with the option of electrotechnical engineering;

• The electronics section with computer engineering, electronic engineering, and telecommunication engineering;

• Mechanical section with options: applied mechanical engineering in the 1st year, mechanical production engineering in the 2nd year, mechanical energy engineering in the 3rd year;

• Aviation section with the option of aeronautical exploitation engineering, air transport;

• Meteorological section with the option of meteorological engineering (in environment), hydrology, and agrometeorology.

METHODOLOGY

1. DESIGN

To conduct this study, we employed a combined quantitative and experimental method (Lugen, 2019). Consequently, we placed greater emphasis on quantitative data collection and analysis to enhance the interpretation of the final results of our research. The experimental study, in particular, enabled us to assess the effectiveness of our two simulation software programs, namely "Circuit Wizard" and "Interactive Physics," in the teaching and learning of physics. To achieve this, students were given the opportunity to create their own experiments using the tested simulators, thereby studying various physical phenomena through hands-on manipulation.

2. SAMPLE

The size of our study sample consists of 100 students (70% men and 30% women), distributed into two groups of 50 students each. Specifically, the first group comprises students in the electrical specialty (n=50), and the second group consists of those in the mechanical specialty (n=50), all registered at ISTA/Kinshasa. This sample was chosen for convenience. According to Mrabet (2017) and Casal and Mateu (2003), the researcher directly and intentionally selects individuals who present themselves at the location where the research is conducted and at the agreed-upon time. It is important to note that these individuals willingly commit to participating in the survey.

3. TOOL: THE QUESTIONNAIRE

The questionnaire is a preferred tool for data collection in many scientific disciplines such as sociology, psychology, demography, sociolinguistics, didactics, etc. (Souaṃes, 2020). Indeed, the questionnaire consists of a set of questions related to the variables that the researcher wants to measure (Hernández Sampieri, 2018). In our study, we employed two specific research questionnaires. The first was administered to the group of students majoring in electricity for the experimentation of the software "Circuit Wizard." The second was distributed to the group of students majoring in mechanics to test the software "Interactive Physics." As stated in the objective of this article, all the questions in our questionnaire were essentially aimed at measuring the impact of the use of these two software programs in the teaching/learning process of mechanical and electrical concepts.

4. COURSE OF ACTION

A working session took place at our host institution's facilities, involving our two groups of students who voluntarily agreed to participate in our study. The first group utilized the "Circuit Wizard" simulation software, while the second group worked with the "Interactive Physics" software. Initially, we communicated the objectives of the work session to our participants. Subsequently, each participant received an individual questionnaire, which they completed on the spot under the supervision of the experimenting teachers. These teachers provided necessary clarifications to facilitate the students' understanding of the expected information.

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6. PRESENTATION OF COMPUTER SIMULATION SOFTWARE USED

Through the various writings in this section of our article, we strive to present in a less verbose manner the software tools that have been exploited throughout the realization of the present study.

Presentation of the " Circuit Wizard " software

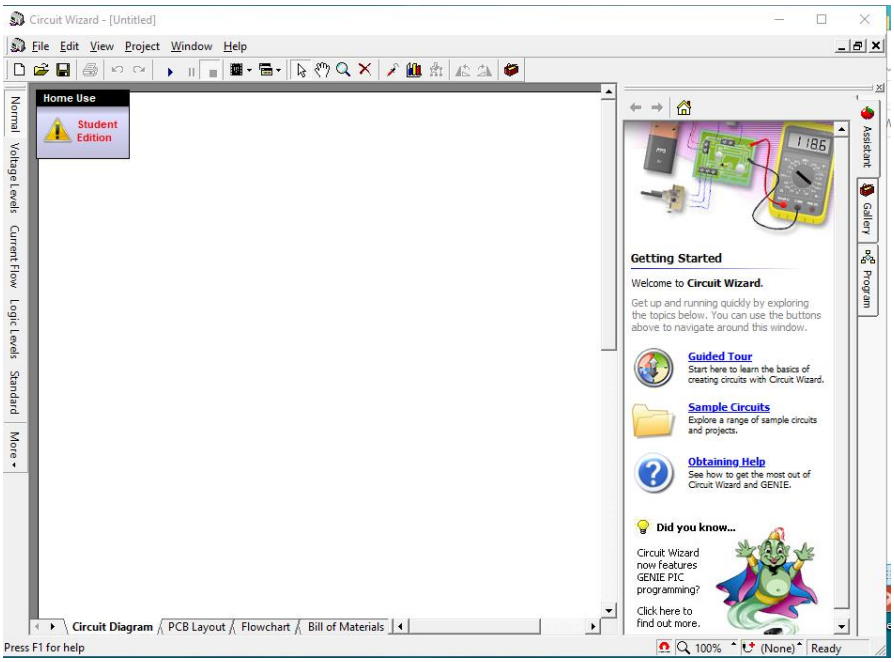

Figure 1: Primary Interface of "Circuit Wizard" Software

(Source: personal realization)

Circuit Wizard is a computer simulator available in both free and paid versions. It is a computer program designed to simulate electrical circuits on the computer. This software is feature-rich, offering a library of tools. Additionally, users can expand their tool library by creating new symbols using standard drawing tools. It is a highly powerful program, allowing users to undertake complete electronic equipment manufacturing projects.

Due to its capabilities, Circuit Wizard is utilized in all stages of such projects, including design, simulation, debugging, and construction (Palacios, 2018). Indeed, with the "Circuit Wizard" software, users have the ability to perform the following tasks

- Design of electronic circuits;

- Construction of the real physical prototype on a test board;
- Design of the printed circuit;
- Construction of the real physical prototype on PCB;
- Functional tests;
- Design of the electronic circuit;
- Circuit simulation;
- Design of printed circuits;
- PCB simulation;
- Construction of printed circuits and functional tests.

It should be noted that this software is compatible with Windows as well as other operating systems, such as MacOS.

Similar to other computer simulation software, the advantages of using Circuit Wizard include:

- Cost savings in terms of prototypes to be tested.
- Time savings in the simulation process.

In conclusion, Circuit Wizard is a user-friendly simulator designed for visual analyses of electrical and electronic circuits. This is why it is widely utilized by mechanical engineers and engineers in related specialties. The software assists them in mastering electrical and electronic circuits (MEP365 Circuit Wizard, 2020).

7. PRESENTATION OF THE " INTERACTIVE PHYSICS " SOFTWARE

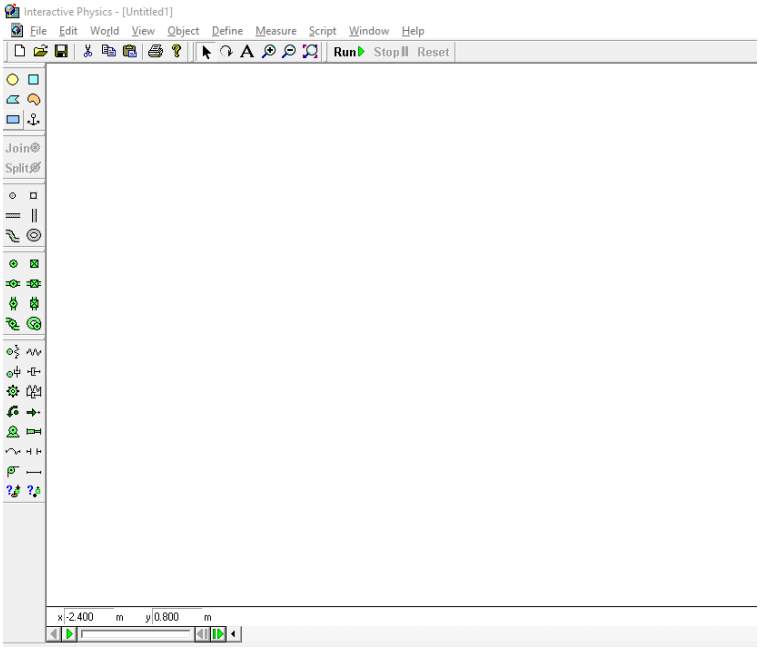

Figure 2: The primary interface of the 'Interactive Physics' software.

(Source: personal realization)

The "Interactive Physics" software is primarily an educational tool, specifically utilized in solid mechanics (2D) and grounded in the principles of Newtonian mechanics (Interactive Physics Simulation Software | Physion, n.d.). The primary purpose of this software is to enable users to accomplish tasks such as:

- Observing the phenomena under study.
- Discovering the laws of physics.
- Exploring the physics phenomena under study (aertia - Interactive Physics, n.d.).

To achieve these objectives, the software relies on icons, which are graphical representations of figures or diagrams of objects (such as springs, wires, extended objects...) (Milot, 1998). The notable strength of Interactive Physics lies in the use of icons to create an intermediate level of abstraction between the real object and its simulated model (Milot, 1998). According to the aertia.com website, Interactive

Physics software is employed in over 12,000 schools worldwide. The software has also received recognition from MacUser magazine as the "Best Educational Product" for several consecutive years. This accolade is one of the reasons we selected this computer simulator.

Interactive Physics is compatible with both Windows and macOS operating systems.

In summary, Interactive Physics software provides various opportunities for learners to comprehend a school subject. For instance, it enables students to grasp diverse physics concepts in a well-designed educational environment. In this context, Interactive Physics immerses students in a virtual laboratory, allowing them to circumvent potentially dangerous or costly experiments. Additionally, it empowers students to conduct experiments that might not be feasible due to the absence of scientific equipment in the physics lab (aertia - Interactive Physics, n.d.).

8. VALIDATION OF THE QUESTIONNAIRE

To validate our research questionnaire, we proceeded as follows:

Literature Review:

We conducted an inventory of papers published under the theme of computer simulation, which included the PhD theses of Demba (2020), El Hassouny (2014), and Chekour (2019). Additionally, we consulted scientific papers published on this same theme by Droui and El Hajjami (2014), Jemaa and Boilevin (2016), and Hallman et al. (2009). Several circular notes from the Congolese Ministry of Higher Education and Universities related to the teaching of physical sciences in Congolese universities and higher institutes were also examined. The insights derived from a comprehensive review of these documents guided the development of the first version of our research questionnaire.

Brainstorming:

Collaborating with the members of our research team and under the guidance of our professor and head of the laboratory, we engaged in a brainstorming session. We thoroughly examined the content of our initial questionnaire version with the aim of objectifying it through our collective perspective. Only after this activity were we able to compose the final version of our research questionnaire.

Statistical analysis

The data collected from the questionnaire were analyzed and processed using SPSS software. This software also facilitated the presentation of our final results in a comprehensible format through the use of diagrams.

ETHICAL CONSIDERATION

Before initiating the research, our host institution authorized our approach. Participants, after receiving assurance of the voluntary nature of their involvement and the ability to withdraw at any time, were encouraged to sign the consent form. To enhance trust, we also pledged to maintain the anonymity of their participation. Emphasizing the importance of ethics and confidentiality, we established a rigorous framework to ensure a respectful and transparent study.

RESULTS

1. RESULTS OF THE EVALUATION OF THE INTERACTIVE PHYSICS SIMULATION SOFTWARE

a) Does the simulation software "Interactive Physics" simplify the learning of the phenomena studied in mechanics?

As illustrated in Figure 3, students from ISTA/Kinshasa affirmed that the Interactive Physics software has facilitated the learning of studied phenomena in mechanics. Specifically, 66% of the students (comprising 44% strongly agreeing and 22% slightly agreeing) concurred with this statement. Only 34% (comprising 26% slightly disagreeing + 8% strongly disagreeing) of these students expressed a negative opinion regarding the use of this software in learning mechanics phenomena.

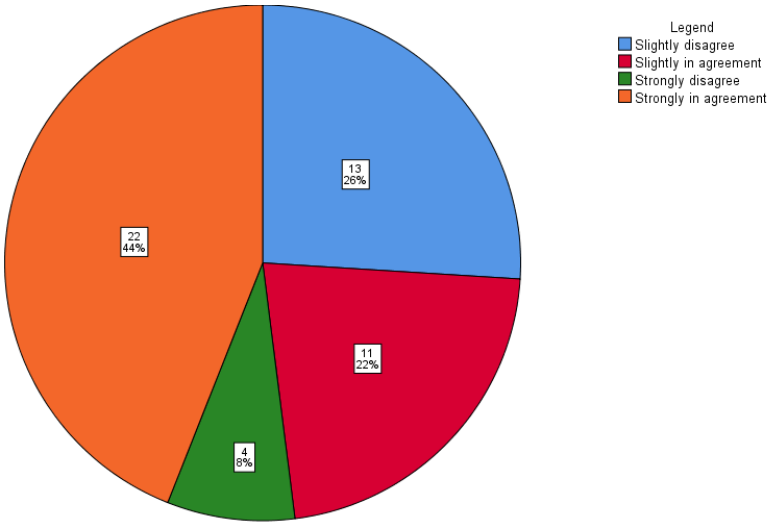

Figure 3. The 'Interactive Physics' software facilitates the learning of phenomena studied in mechanics.

(Source: personal realization.)

b) Did the simulation software "Interactive Physics" reduce certain difficulties in the acquisition of concepts concerning the notion of the Laws of Mechanics?

As for the question of whether certain difficulties related to the appropriation of concepts concerning the notion of the laws of mechanics were reduced thanks to the pedagogical use of the software " Interactive Physics ", the results show that this simulation software was effective on this aspect of the learning of our participants. For 58% of the students (the sum of 32% slightly agree and 26% strongly agree) confirmed the effectiveness of the pedagogical use of "Interactive Physics" in the process of assimilation of the concepts already mentioned above. Only 42% of these students think the opposite of what the majority of them say about the question asked.

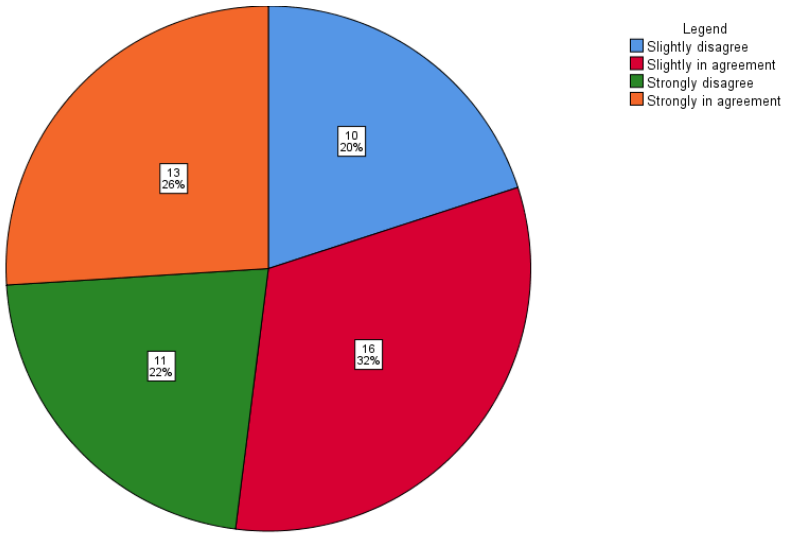

Figure 4. The 'Interactive Physics' software alleviates some of the challenges associated with acquiring concepts related to the Laws of Mechanics.

(Source: personal realization.)

c) In your opinion, is the simulation software "Interactive Physics" easy to use?

Regarding the question of whether the Interactive Physics software is easy to use, we found that 78%

of the students consider the use of this simulation software to be convenient (see Figure 5). This is a large percentage (the sum of 38% slightly agree and 40% strongly agree). Only 22% (the sum of 20% slightly disagree and 2% strongly disagree) of the latter feel that Interactive Physics is not easy to use.

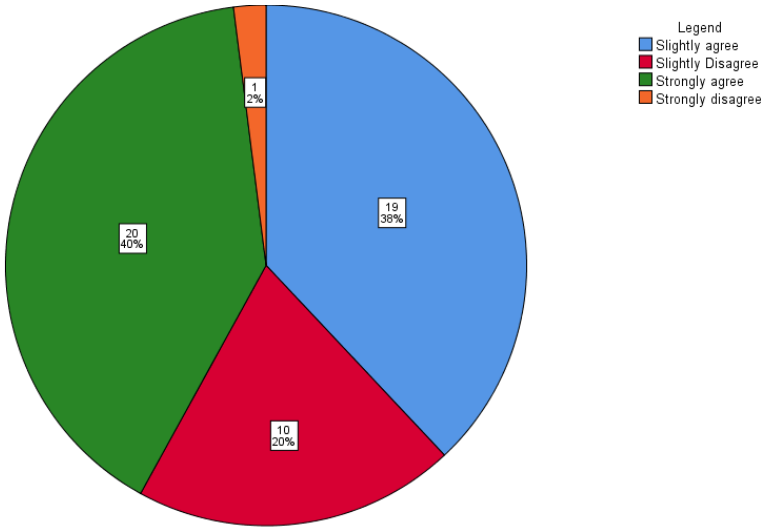

Figure 5. The 'Interactive Physics' simulation software is user-friendly

d) In your opinion, can the simulation software "Interactive Physics" be used in the learning of the different phenomena studied in mechanics?

In response to this question, we found that 60% (the sum of 26% slightly agree and 34% strongly agree) of the participants agree with the pedagogical use of the computer simulator "Circuit Wizard" in their learning of electricity at ISTA/Kinshasa. On the other hand, 40% (the sum of 22% slightly disagree and 18% strongly disagree) of respondents were pessimistic about the use of this simulation software in their learning.

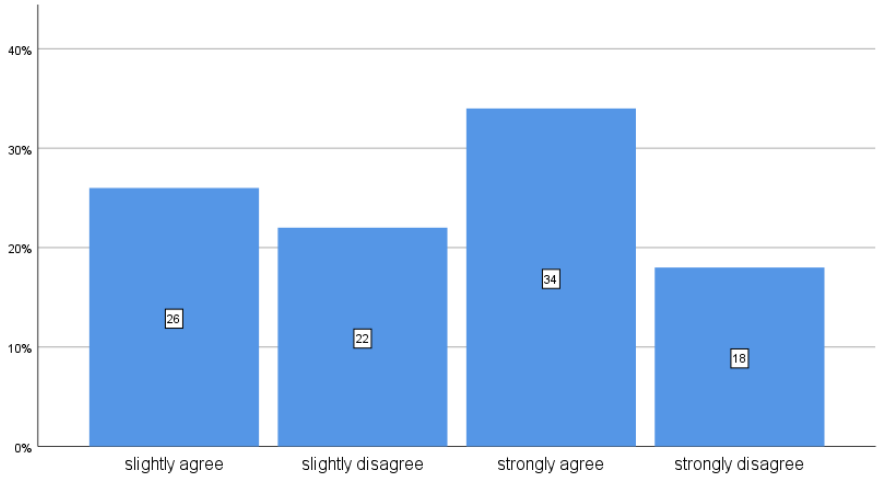

Figure 10. *The incorporation of the 'Interactive Physics' simulation software in the teaching of mechanics at ISTA/Kinshasa.*

More than the majority of participants, 82% (the sum of 28% slightly agree and 54% strongly agree), stated that the Interactive Physics simulator can be used in their learning of mechanics at ISTA/Kinshasa. Only 18% (the sum of 2% slightly disagree and 16% strongly disagree) of the students consider it less effective for use in learning mechanics at their institute of higher learning.

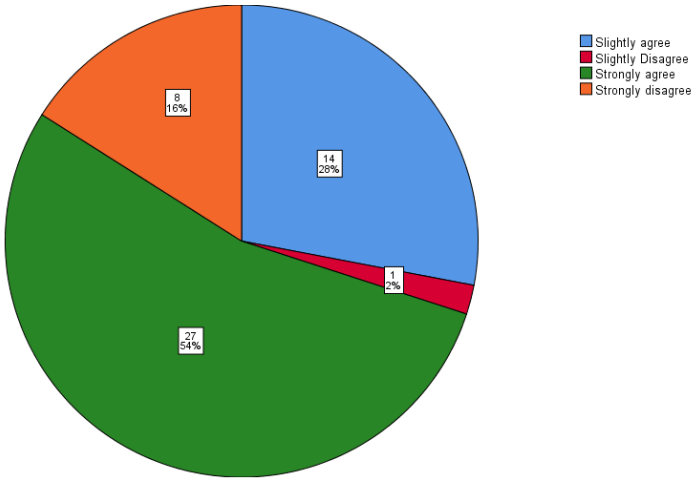

Figure 6. The integration of the 'Interactive Physics' simulation software in the teaching of mechanics at ISTA/Kinshasa.

2. RESULTS OF THE EVALUATION OF THE "CIRCUIT WIZARD" SIMULATION SOFTWARE

a) Does the "Circuit Wizard" simulation software simplify learning about the electrical phenomena studied?

The results show that 60% (the sum of 32% slightly agree and 28% strongly agree) of the students consider that the "Circuit Wizard" simulation software facilitated their understanding of the electrical phenomena studied in class. On the other hand, 40% (the sum of 26% slightly disagree and 14% strongly disagree) of them stated that they did not agree that this software simplified the learning of these phenomena studied in class.

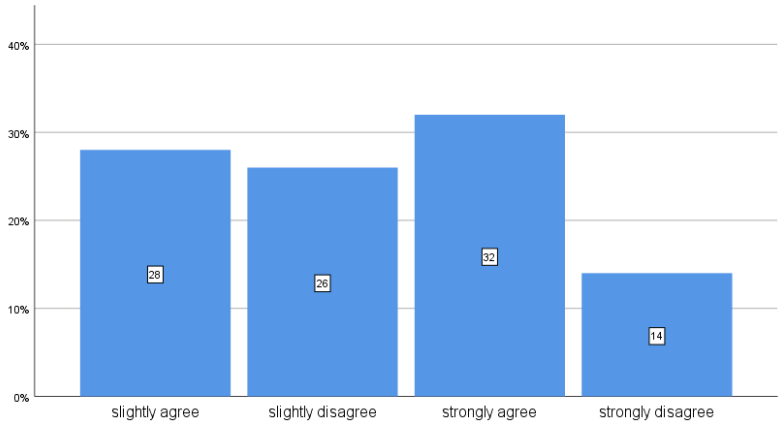

Figure 7. The integration of the 'Interactive Physics' simulation software in the teaching of mechanics at ISTA/Kinshasa.

b) Did the "Circuit Wizard" simulation software reduce certain difficulties in the acquisition of concepts related to the notion of the Laws of electrical circuits?

With regard to the impact of the "Circuit Wizard" software on the reduction of certain difficulties related to the comprehension of concepts related to the notion of electrical circuits, a valuable rate of 76% (the sum of 28% slightly agree and 48% strongly agree) of the opinions of our students confirm that the said software has indeed reduced these difficulties. On the other hand, only 30% (the sum of 20% slightly disagree and 4% strongly disagree) of the participants think that the Circuit Wizard software has not produced any positive effect on this specific topic.

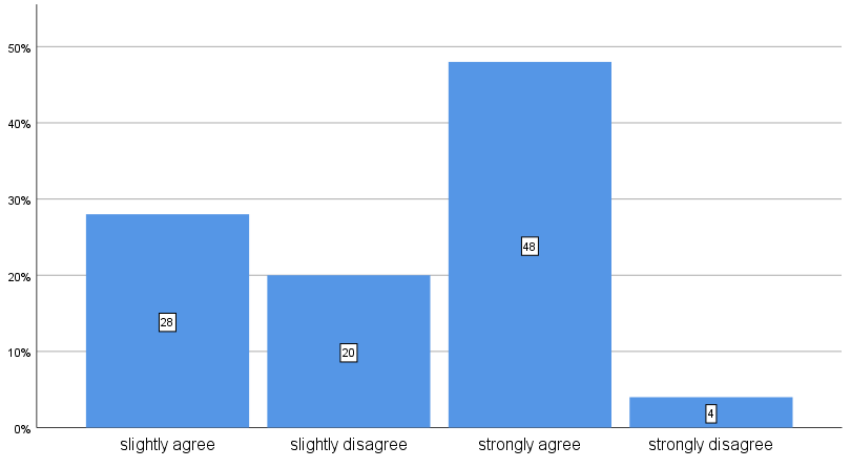

Figure 8. The 'Circuit Wizard' software alleviates some of the challenges associated with acquiring concepts related to the Laws of Electrical Circuits.

c) In your opinion, is the "Circuit Wizard" simulation software easy to use?

According to the results collected in relation to the question of use of the "Circuit Wizard" software, 64% (the sum of 28% slightly agree and 36% strongly agree) of the ISTA/Kinshasa students consulted in this study say it is easy to use. Another 36% (the sum of 28% slightly disagree and 8% strongly disagree) find it difficult to use.

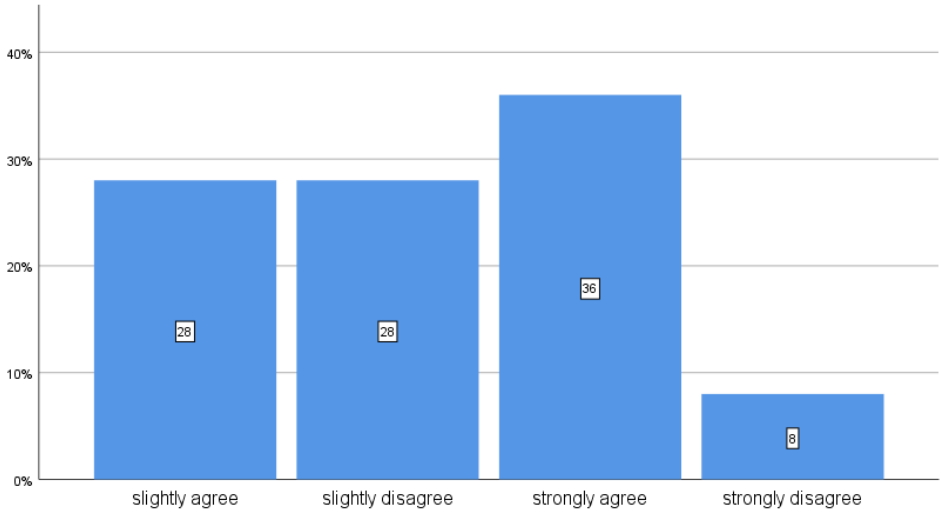

Figure 9. The 'Circuit Wizard' simulation software is user-friendly.

d) In your opinion, can the simulation software "Circuit Wizard" be used in the learning of the different electrical phenomena to be studied?

In response to this question, we found that 60% (the sum of 26% slightly agree and 34% strongly agree) of the participants agree with the pedagogical use of the computer simulator "Circuit Wizard" in their learning of electricity at ISTA/Kinshasa. On the other hand, 40% (the sum of 22% slightly disagree and 18% strongly disagree) of respondents were pessimistic about the use of this simulation software in their learning.

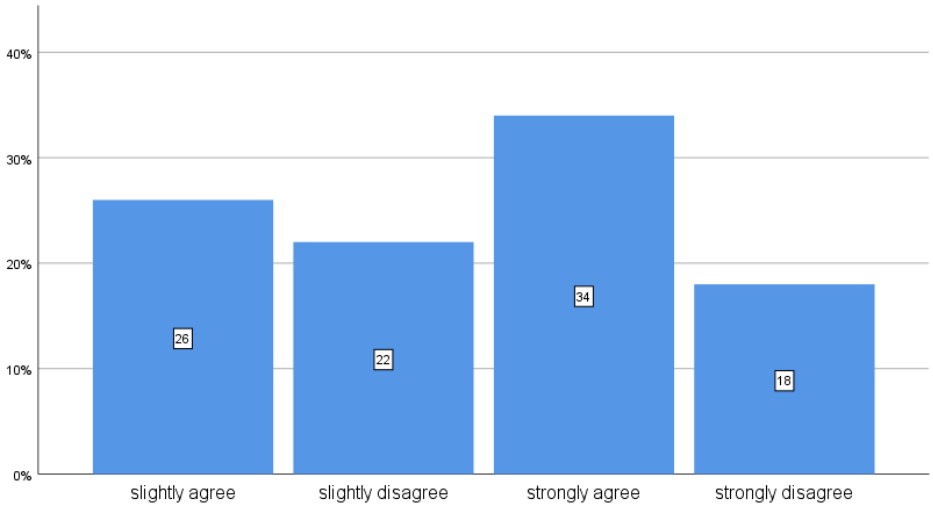

Figure 10. The incorporation of the 'Interactive Physics' simulation software in the teaching of mechanics at ISTA/Kinshasa.

DISCUSSION AND CONCLUSION

As we have well underlined in the introduction, our objective through this study consisted first of all in identifying the benefits and advantages resulting from the use of the computer simulation in the process of acquisition of concepts relating to the physical phenomena, those of mechanics and electricity, in particular. Then, we had as a second objective, that of trying to appreciate the effectiveness of our computer simulators "Circuit Wizard" and "Interactive Physics" used by the students of ISTA /Kinshasa.

Indeed, all the results obtained show that these two computer simulation software tested with the students produced more than satisfactory effects (figures 3, 4, 7 and 8). These results coincide with those of the study conducted by Akimana et al. (2019). Thus, these results make even more sense since the use of the computer simulator nowadays as a didactic tool, implies changes in the way we learn science in or out of the university (García-Martinez and Fallas-Vargas, 2022). In other words, these results show us that computer simulation would primarily be a good alternative to facilitate students' understanding of the physics concepts studied in class (Droui et al., 2014). It would also be a credible alternative to alleviate the problem of the lack of practical work noted at this ISTA/Kinshasa. level due to the lack of adequate scientific equipment in the laboratories (N'djoli et al., 2022).

In this case, computer simulation can play a salutary role. That is to say, the use of this techno-pedagogical approach will allow the students to calmly redo the experiments not carried out at ISTA/Kinshasa and to simulate the real experiments which prove to be dangerous to carry out in the laboratory or too expensive (Hebenstreit, n.d.). This also means that computer simulation offers the possibility to work on a virtual laboratory (PhET Interactive Simulations, n.d.).

Therefore, our participants clearly expressed their support for the idea of integrating these two software programs into the learning process of mechanics and electricity at their academic institution (Figures 6 and 10). Thus, the "Circuit Wizard" software received 60% of the votes cast for its integration into the learning process, while the "Interactive Physics" software received 82% of the votes cast. These results are in perfect agreement with the research published by Elouardani (2016).

That said, the selection of the proposed software for this study was driven by three criteria:

- The ease of use of these software packages by students (Figures 9 and 5);
- The fact that the software is free to download from the Internet (student or teacher version);
- The effectiveness of these programs in facilitating the understanding of the concepts or notions to be assimilated.

Furthermore, we believe that it is imperative to support the use of computer simulation in pedagogy. This is why we recommend its use through the present study, and this, by the preparation of the pedagogical sheet. Indeed, it will help the teacher in charge of the course of mechanics or electricity via the computer simulators "Circuit Wizard" and "Interactive Physics" to guide his session in audience and even to succeed. Also, we plan to make available very detailed guides for the use of each simulator. This will help the physical science teachers in our school to better master these simulators.

In short, we can see that the results for the Interactive Physics software are much better than those for the Circuit Wizard software. We can explain this situation by the fact that during the course of the experiments, the majority of the students in the group that worked on the "Circuit Wizard" simulator had difficulty understanding the different functions of this software because they were completely in English. Moreover, it should be remembered that in the Democratic Republic of Congo the official language of instruction is French.

In addition to the language barrier, we can also mention the fact that the different functionalities of the software in question are somewhat hidden compared to those of the "Interactive Physics" software, which are directly visible in the work area. It is therefore logical that these students have difficulties in such a situation where they are called upon to perform double intellectual gymnastics on "Circuit Wizard". They have to find the location of the objects to be simulated and master their operation. So, faced with this situation, the teacher-experimenter associated with this group of students had to clearly explain each task to be carried out on this software in order to allow the students to have the required level of understanding in this regard.

As in every study, there are always some limitations inherent in the work carried out that deserve to be taken into account in order to improve its quality. In the case of this research, we worked with a sample of only 100 students from ISTA/Kinshasa. However, we would have liked to have had a more representative sample size, for example, estimated at 1000 students, in order to make a more conclusive generalization. Due to a lack of technical, logistical and financial resources, we had to work with the hundred or so students at ISTA/Kinshasa. However, the information presented in this paper is highly relevant.

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